

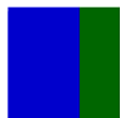
River Valley Ecosystems Study

Boreal Owl Component

Progress Report
Work Carried Out in 2005

by
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January 2006



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Monitoring and Research*

**Ressources naturelles
et Faune**

Québec 

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INTRODUCTION

The river valleys located in the military training area (MTA) of Quebec-Labrador are particularly appealing for low-level flying because they provide a natural corridor appropriate for training routes and they enable pilots to practise radar detection avoidance. Given the relatively large number of low-level training flights occurring in river valleys and the biological importance of those valleys, the Institute for Environmental Monitoring and Research (IEMR) has developed a research program over the past few years to investigate the impact of overflights on the ecological components of river valleys. The first work to be carried out was designed primarily to identify certain species that are closely associated with the river valleys and could be targeted for more specific studies.

Birds of prey are located at the top of the food chain, and this makes them vulnerable to stress factors and changes in their habitat. They are therefore excellent indicators of the health of the environment, and several species have been chosen as indicator species in a number of locations around the world. In the area of Quebec-Labrador used for low-level flying, studies have been carried out in an attempt to identify the effects of the flights on diurnal birds of prey, more specifically the osprey (*Pandion haliaetus*) (Trimper et al. 1998ab, Thomas 1999). However, the increase in military activities at night has recently brought to light the need to initiate studies of nocturnal species.

Searching for nocturnal raptor nests for such studies can involve considerable effort in the field and result in the discovery of a relatively small number of nests, particularly in regions with no access roads. The best way to find an adequate number of nests with relatively little effort is to install nesting boxes for species that nest in cavities. In this context, the boreal owl (*Aegolius funereus*) is the most attractive target species in the Quebec-Labrador region. Not only does the boreal owl readily use nesting boxes (Korpimäki 1981, 1985), but it is also reported that, in northern latitudes, this owl is confined mainly to riparian forests owing to the relative scarcity of appropriate breeding habitats outside the river valleys (Mossop 1997). Consequently, the home range of the

boreal owl extends for long distances along watercourses (Hayward & Hayward 1993). Such habitat use by the boreal owl should therefore favour this species' presence in the ecosystems targeted for study in the low-level flying area, making it an ideal indicator species for possible studies designed to evaluate the repercussions of low-level overflights.

The *Direction de la recherche sur la faune* of the *Ministère des Ressources naturelles et de la Faune, Secteur Faune Québec*, therefore proposed that a study be undertaken to that effect, and some preliminary work got under way in 2003: a network of nesting boxes was installed along the Natashquan and Aguanish rivers in order to monitor boreal owl nesting (Maisonneuve 2004). The first full season of data collection was completed in 2004. However, major problems with predation by the American marten (*Martes americana*) and disturbance by the porcupine (*Erethizon dorsatum*) interfered considerably with the obtaining of meaningful results, and anti-predator and anti-porcupine devices had to be installed (Maisonneuve 2005). The nesting boxes were monitored again in the spring of 2005, and this report presents the results that were obtained during the nesting season.

HYPOTHESES

Low-level flying could affect boreal owls in various ways. First, the flights could affect the hearing ability of these birds, which depend greatly on that sense to feed themselves. This could lead to a decline in the feeding efficiency of the adults. The number of eggs laid by the female depends to a large extent on the energy reserves she has built up (Korpimäki 1987), which in turn depend on the hunting success of the male and the female. Boreal owls live in the same area year-round, and the number of eggs laid serves as an indicator of the feeding conditions in their home range. Also, it has been shown that large clutches produce more young (Korpimäki 1987). During incubation and rearing, the female normally stays on the nest, and the male provides food for her (Hayward & Hayward 1993). Consequently, a reduction in hunting efficiency could have an impact on nesting effort, egg-laying effort, and survival of the young. But it is recognized that the nesting effort of boreal owls is closely related to the availability of prey (Löfgren et al. 1986, Korpimäki 1988, Hörnfeldt & Eklund 1990). In northern regions, small mammal populations go through cycles characterized by years of very low abundance, which have an impact on the breeding effort of boreal owls (Korpimäki 1981, Löfgren et al. 1986, Hörnfeldt et al. 1990). During those lean years, the owls may even refrain from reproducing. It is therefore necessary to know the population levels of small mammal species so as not to wrongly attribute the observation of a poor breeding effort to low-altitude flights alone.

Fault bars, which have been particularly well documented in the scientific study of raptors, are malformations in the feathers that were initially associated with a scarcity of food resources and low energy reserves. However, recent work leads us to believe more and more that these fault bars may also be caused by stress factors (Machmer et al. 1992, Negro et al. 1994, Bortolotti et al. 2002) and could therefore be used to compare stress levels between different sectors. Whether fault bars are caused by a reduction in food intake or by stress factors, their number and frequency of occurrence should be higher in juvenile birds reared in sectors affected by low-level flying. Causes of stress during feather development in adult females may make it possible to predict their reproductive

status (Bortolotti et al. 2002); consequently, the presence of fault bars in females could also be investigated in an attempt to explain nesting success.

On the basis of these hypotheses, different parameters can therefore be looked at with a view to determining the possible effects of low-level flying:

1. Nesting box occupancy rate
2. Egg-laying effort (number of eggs)
3. Nest attentiveness of the female, and food supply provided by the male
4. Nesting success
5. Survival of the young
6. Number and frequency of fault bars in the feathers
7. Availability of food (abundance of small mammals).

SELECTION OF STUDY SECTORS

The Natashquan River was selected for the study for the following reasons:

1. Along with the Petit-Mécatina and Olomane rivers, the Natashquan is among the rivers most affected by the low-level flying carried out in Quebec, where nearly 60% of all flights are made.
2. Of these three rivers, the Natashquan is the one where the habitats along the banks are the most homogeneous, making it easier to select suitable sectors for experimental/control comparisons.
3. The Natashquan River is the only one that is easily navigable over long distances.
4. The mouth of the Natashquan River is located near the village of Natashquan, which is accessible by road, thus facilitating all the logistics of the project.

The stretch of the Natashquan River located immediately to the north of the southern boundary of the training area was therefore selected as an experimental sector (Figure 1). Since the section of the Natashquan River located to the south of the boundary of the training area is not long enough to install the required number of nesting boxes (see “Methods” section), a stretch of the Aguanish River, situated only 20 km to the west and presenting roughly the same habitat characteristics, was selected to complete the control sector (Figure 1).

METHODS

Network of Nesting Boxes on the Natashquan and Aguanish Rivers

On the basis of the estimates of the sample sizes required to obtain a sufficient level of precision regarding boreal owl productivity parameters (Hayward et al. 1992), 300 nesting boxes were installed in September 2003 in each of the river sections selected, for a total of 600. Since the rivers being studied are relatively wide, they probably impede boreal owl movements from one bank to the other, such that the home ranges should be considered separated by the rivers. Consequently, nesting boxes could be installed on both banks. A distance of 0.5 km between each of the nesting boxes is recommended (Hayward et al. 1992). However, because of the small amounts of precipitation on the North Shore in the summer of 2003, the level of the rivers was particularly low when the nesting boxes were installed in September. Vast stretches of sand banks were exposed in certain locations, making it more difficult to reach the river banks in a number of sectors. Those sectors had to be avoided to speed up the work, and the locations selected for the installation of nesting boxes therefore had to be spaced farther apart. The distance of 0.5 km therefore represents the minimum distance between two nesting boxes on the same bank. GPS was used to determine the exact location of all the nesting boxes.

In addition, anti-predator and anti-porcupine devices were installed in the fall of 2004 in an attempt to solve the problems of predation by American martens and disruption by porcupines that occurred in the spring of 2004 (Maisonneuve 2005). A piece of sheet metal was therefore attached to the front of each nesting box. The piece of sheet metal, which extends over the perimeter to prevent predators from gaining access to the nesting box, has a hole through it to allow the owls to get in and out. In addition, a sleeve of sheet metal was placed around the trees, just beneath the nesting boxes, to prevent porcupines from climbing up.

During the spring of 2005, a single visit, from May 17 to 23, was made to the network of nesting boxes. As in 2004, that visit was made by motorboat (18-foot canoes), and only a

few impassable thresholds required the slinging of the boats by helicopter. Given the total absence of nesting noted after a few days (see “Results” section), the work was stopped after 300 nesting boxes were visited.

Network of Nesting Boxes in the Sept-Îles Region

In January 2003, 99 nesting boxes were installed in two sectors near the city of Sept-Îles: a coastal sector located to the east of the city, where 67 nesting boxes were installed along Route 138; and another sector located inland, where 32 nesting boxes were installed along the road leading to the hydroelectric facilities on the Sainte-Marguerite River (SM3). In 2003, the total lack of occupied nesting boxes in the network located in the coastal sector (Maisonneuve 2004) prompted us to move those 67 nesting boxes to the north of the others along the SM3 route in December 2003. In 2004, weekly visits were made to that network of 99 nesting boxes in order to collect data that could help in understanding certain results obtained along the Natashquan and Aguanish rivers, where the visits had to be spaced further apart owing to the region’s inaccessibility and the costs that more frequent visits would have entailed. The same approach was planned for 2005, but the monitoring had to be stopped after the first visit, at which time a total absence of nesting was noted (see “Results” section). That visit to the 99 nesting boxes took place from April 27 to May 12.

Trapping of Small Mammals

In 2003, 10 trapping stations were distributed over closed and open forests (Maisonneuve 2004). In 2004, the stations in open environments were abandoned in order to increase the trapping effort in closed environments (Maisonneuve 2005). Consequently, a small mammal trapping campaign was carried out again in 2005 in the same 10 stations in closed environments (Figure 1). Initially, that campaign was to take place in September, as it had in 2003 and 2004. However, owing to the observation in May that the boreal owls had not started nesting, it was decided to move the campaign to July in order to

determine whether those results could be attributed to poor food availability at the time of nesting.

At each of the stations, 100 kill traps (Victor M035) were systematically set every 10 metres along four lines 250 metres in length, also spaced 10 metres apart. Owing to the configuration of station #5, the traps had to be distributed over six trapping lines. The traps, which were baited with peanut butter, remained in place for three nights and were visited every day. The specimens caught were put in plastic bags, and then labelled and placed in a freezer at the end of the day. They were subsequently identified in the lab by means of skull characteristics and dentition (Lupien 2001, 2002). The specimens of the genus *Peromyscus* were identified by means of mitochondrial DNA (Tessier et al. 2004). The abundance of small mammals was expressed in terms of number of captures per 100 trap/nights. A correction reflecting the number of traps sprung accidentally was included in the calculation of that index (Nelson & Clark 1973). Trapping took place from July 6 to 9 in the training area and from July 9 to 13 in the control sector. The Kruskal-Wallis test (NPAR: Kruskal, SYSTAT 11 Statistics II, 2004) was used to carry out a year-to-year comparison of capture success. Only the data collected at the stations located in closed environments were used in carrying out that analysis.

Food Selection of Boreal Owls

The contents of the nesting boxes that had been occupied by boreal owls during the 2004 season were sampled at the end of that season, placed in plastic bags, and frozen. The material thus collected was cleaned in the laboratory to recover the remains (bones, dried carcasses) of prey that had accumulated in the nesting boxes. Those prey remains were identified during the winter of 2004-2005. Where available, the skull structures were used to identify the prey by species (Lupien 2001, 2002) in order to establish a minimum number of prey (Marti 1987). The dried carcasses, which were often without skulls, were classified according to two broad categories: Arvicolinae (voles) and Soricidae (shrews).

The captures made during the small mammal trapping campaigns served to determine the availability of the different types of prey to boreal owls. Since those captures provide only an estimate of the availability of each species, an χ^2 test for homogeneity was used to ascertain whether boreal owls catch their prey according to its availability or whether they select certain species (Marcum and Loftsgaarden 1980). The least abundant species of rodents (*Microtus pennsylvanicus*, *Peromyscus maniculatus*) were grouped together in the same category (other rodents) in order to comply with the test application criteria (no more than 20% of theoretical frequencies below 5). In the event that this test indicates a significant difference, the Bonferroni method is used to calculate confidence intervals for each species or category of species (Miller 1966). A species or category of small mammals is considered selected when the confidence interval is below 0. A species is used in a lesser proportion than its availability when the confidence interval is above 0, while a confidence interval of 0 indicates that use is proportional to availability.

RESULTS

Network of Nesting Boxes in the Sept-Îles Region

During the visit to this network, no signs that the nesting boxes had recently been used by boreal owls were detected. All of the signs of owl occupation noted (old feathers and broken eggs) dated back to the previous year. All of the contents of the nesting boxes were cleared out to make it easier to detect signs of occupation during possible subsequent visits. Those contents will eventually be cleaned and sorted so that only the prey remains are left. Those remains will be identified, thus making it possible eventually to examine the food selection of boreal owls.

Network of Nesting Boxes on the Natashquan and Aguanish Rivers

For various reasons, certain nesting boxes were inaccessible or were no longer functional. Most of them (11) were surrounded by water at the time of the visit, and one was attached to a tree that had blown over. In all, 288 nesting boxes were therefore inspected in the control sector. None of the nesting boxes examined showed any damage caused by rodents. The total absence of nesting noted in this sector, combined with the same finding for the network of nesting boxes in the Sept-Îles region, led to the hypothesis that the northern regions had been hit by a generalized lack of food and that it was unlikely that boreal owls had a greater tendency to nest in the training area. It was therefore decided not to monitor the nesting boxes any further in 2005.

It should be noted that, during the field work carried out as part of the bat research project (Maisonneuve, under preparation), it was possible to fly over the section of the Natashquan River located in the training area in July. During those flights, it was noted that there had been a major forest fire in the study area affecting a distance of a few kilometres along the river's edge.

Trapping of Small Mammals

In all, only 32 small mammals belonging to four species were caught (Table 1). The Gapper's red-backed vole (*Clethrionomys gapperi*) and the masked shrew (*Sorex cinereus*) accounted for most of the captures, representing nearly 90% of the specimens. Captures were three times more abundant in the control sector, but the very low abundance in both sectors makes any statistical comparison risky. The most useful aspect of the data collected in 2005 is that they make it possible to compare capture success with that obtained in previous years.

During the two preceding years, no difference was noted between the control sector and the training area (Maisonneuve 2005), and the data from the two sectors could be grouped together in order to make comparisons between years (Maisonneuve 2005). The Kruskal-Wallis test comparing the six closed sites covered in 2003 with the 10 sites covered in 2004 and 2005 reveals an obvious difference in capture success ($H = 18.6$, $P < 0.001$) (Figure 2). It is fairly obvious that the difference between the three years is attributable to a major decline in captures in 2005.

Food Selection of Boreal Owls

It was possible to collect prey remains from 12 nesting boxes where boreal owls had initiated nesting in 2004. The number of prey that had accumulated in the nesting boxes varied from 1 to 79 (median = 10.5). Only five nesting boxes contained more than 10 prey. Nearly 60% of the 274 prey encountered could be identified and classified according to six different species or groups of species (Table 2). The Gapper's red-backed vole and the heather vole (*Phenacomys intermedius*) accounted for 90% of the specimens identified. The unidentified prey were mostly voles (98%) as well. One of the nesting boxes contained the remains of a dragonfly and the bones of a frog's foot.

A comparison of the proportion of the different species of small mammals found in 2004 in the nesting boxes with those obtained the same year during the trapping campaign indicates a significant difference ($\chi^2 = 97.19$, $df = 4$, $P < 0.005$). The confidence intervals

obtained for each species (Table 3) show that only one species, the heather vole, was the subject of obvious selection by boreal owls (Figure 3). The Gapper's red-backed vole is the only species for which the proportion used was lower than its availability. The other species were used in proportion to their availability in the environment.

DISCUSSION

In 2005, we were supposed to be able to check the effectiveness of the anti-predator and anti-porcupine devices installed in 2004 on all of the nesting boxes in the network on the Natashquan and Aguanish rivers. The sheet metal placed around the trees was very effective in preventing porcupines from reaching and chewing the nesting boxes since none of the 288 nesting boxes examined showed any damage. Most of the nesting boxes damaged by rodents in 2004 were located in the training area, and the nesting boxes in that sector were not visited in 2005. Yet there is no reason for the devices to be less effective in one sector than in another. However, the total absence of nesting noted in May obviously makes it impossible to come to any conclusions about the effectiveness of the anti-predator devices. One might believe that the boreal owls failed to nest because the presence of the devices made the nesting boxes less attractive to them. However, boreal owls also completely abandoned the network of nesting boxes in the Sept-Îles region, which were not equipped with the devices. In addition, similar devices have been used successfully in Switzerland (Ravussin et al. 2001). It seems obvious that some other factor influenced boreal owl reproduction in 2005, and our data make it possible to present an explanation in the following sections.

Boreal Owl Nesting and Small Mammal Population Cycles

When this project was in the planning stage, the annual small mammal trapping campaign was scheduled for the month of September. That time was chosen primarily because certain studies have shown that the abundance of food in the fall accounts for the breeding effort among boreal owls the following spring (Hörnfeldt et al. 1990) and also because it is much more complicated to carry out such a campaign in March or April, at which time boreal owl nesting has started, owing to the thick layer of snow still on the ground. However, Korpimäki (1994) has also shown that the density of nesting boreal owls can, at least in certain regions and under certain snow conditions, be influenced by the abundance of small mammals at the time when nesting is initiated, rather than by the abundance of small mammals the previous fall. Boreal owls would be able to detect

changes in the abundance of their food and react quickly by dispersing to seek out more suitable sectors.

In that context, and given the observation in May 2005 that boreal owls had not initiated nesting in our study area, the trapping campaign was moved to July in order to determine whether those results could be attributed to poor food availability at nesting time. By doing that, we wanted to prevent an increase in the number of small mammals in the summer from interfering with the possibility of detecting such a decline. Our results indicate clearly that small mammal populations collapsed rapidly between September 2004, at which time capture success was still excellent, and July. It is easy to assume that this drastic decline in the population of small mammals occurred before the month of March, when boreal owls start to mark out their territories, which would explain the total lack of boreal owl nesting in 2005.

In the northern parts of Europe, many studies have shown that populations of small mammal, particularly voles, go through cycles of population fluctuation at intervals that can vary from three to five years (Hörnfeldt 1978, Hansson and Henttonen 1985, Henttonen et al. 1985, Hanski et al. 2001). Those cyclical fluctuations would be much less obvious farther to the south where predators would have access to a greater abundance of alternate prey (Hanski et al. 1991). Such cyclical fluctuations are very well known among other species of North American mammals, including the lemming on the tundra (Pitelka et al. 1955, Wilson et al. 1999) and the hare in the boreal forest (Krebs et al. 2001). Until quite recently, it appears that it was still taken for granted that most North American species of vole did not really go through regular cyclical fluctuations in population or that those fluctuations were attenuated by the presence of alternate prey such as the snowshoe hare (*Lepus americanus*) (Hansson and Henttonen 1985, Boutin et al. 1995, Fryxell 1998). However, a recent analysis of winter observations of northern owls in the inhabited regions of the northeastern part of North America shows that the boreal owl invades those regions every four years and that those invasions seem to be associated with drops in small mammal populations in their breeding areas (Cheveau et al. 2004). According to that study, 2004 was supposed to be marked by a decrease in the

population of small mammals, which our results confirm, that decline seeming to have occurred between September 2004 and March 2005. Also, certain observations indicate as well that the major shift towards the south expected for 2004 did in fact occur. As a result, the captures of boreal owls carried out in the fall at the Observatoire d'oiseaux de Tadoussac were the most abundant ever recorded at that location (Rivard and Drolet 2005), and sightings of other northern owl species, such as the great grey owl (*Strix nebulosa*) and the Northern hawk-owl (*Surnia ulula*), were also more abundant than they had ever been throughout the eastern part of North America in the winter of 2004-2005 (Bannon et al. 2005 and 2006, Gu nette 2005).

Although those sightings tell us that small mammal populations do seem to be undergoing cyclical fluctuations and that the interval between those cycles is four years in eastern North America, it would be good to know how fast those populations can rebound and thereby enable boreal owl populations to start reproducing again. That knowledge would help tremendously in the planning of future inspection visits to the networks of nesting boxes on the North Shore in the event that there is still an interest in continuing the work.

In Scandinavia, after small mammal populations experience a crash, they rebound very quickly, as early as the next year, and boreal owls react just as quickly. Indeed, in Finland, after almost no boreal owl nesting during certain bad years, nesting box occupancy rates ranging from 8% to 30% were obtained the following year (Korpim ki 1994). Data collected in the northern part of Sweden also indicate that boreal owls nest in large numbers the year after a decline in small mammal populations (H rnfeldt et al. 1990). In view of the differences that exist between the two continents in terms of the composition of small mammal and predator communities and their possible influence on the cyclical fluctuations in small mammal abundance (amplitude and frequency), it would be presumptuous, at least for the time being, to suggest that high occupancy rates could be obtained in the spring of 2006 in our networks of nesting boxes on the North Shore. A visit to those nesting boxes in 2006 would make it possible to ascertain quickly whether that trend may exist in North America as well.

The cyclical fluctuations in vole populations are generally synchronized over distances that can reach 500 km (Huitu et al. 2003, Korpimäki et al. 2004). Unfortunately, we have no small mammal trapping data for the Sept-Îles region with which to determine whether the population crash observed near Natashquan affected that region too. But the total lack of nesting by boreal owls in our network of nesting boxes in the Sept-Îles region seems to indicate that the situation was the same in that region, located 350 km away from our trapping stations on the Natashquan River. Other observations support this hypothesis as well. First, during the winter of 2004-2005, an experienced trapper who has been trapping martens in the region for many years observed boreal owls in his traps for the first time. They were apparently starving and were attracted by the bait. Furthermore, an examination of the carcasses of boreal owls found dead in the region that same winter indicates that the birds were very thin and likely died of hunger. It therefore appears that the fluctuations in small mammal abundance are almost the same in the Sept-Îles and Natashquan regions.

Food Selection of Boreal Owls

Although numerous studies in Europe have looked at the diet of boreal owls during the breeding season, there has been little study of this topic in North America. Only three studies could be found in the literature, and they were all carried out on the western side of the continent, i.e., in the states of Colorado (Ryder et al. 1987), Montana, Wyoming and Idaho (Hayward et al. 1993), and Alaska (Whitman 2001). The only other study on this topic is that of Catling (1972), who looked at the diet of the boreal owl during a winter invasion in southern Ontario. Our study is therefore the first to look at the diet of this species during the breeding season on the eastern side of the continent. As was demonstrated in Europe (Korpimäki 1981), in North America, mammals also account for most of the species eaten by boreal owls, and voles are always among the dominant species, even though the species represented may vary from one region to the next (Table 4).

On the western side of North America, birds account for 3% to 7% of the prey taken by boreal owls (Table 4). Several European studies have shown that different species of birds can be taken by boreal owls, and the relative abundance of this type of prey increases in years when there is a low abundance of small mammals (Korpimäki 1981). The total lack of bird remains in our nesting boxes could therefore be attributed to the fact that, as our trapping results showed, the availability of small mammals was particularly high in 2004. The occasional consumption of amphibians has been mentioned as well with respect to a number of species of nocturnal birds of prey (Errington 1932, Hamilton 1941, Gross 1944, Fitch 1947, Earhart and Johnson 1970, Stewart 1969, Marti 1976). However, to our knowledge, the sighting of a frog's foot in one of our nesting boxes is the first published mention of predation of an amphibian species by the boreal owl.

The use of insects as food by boreal owls has been mentioned regularly as well, although this is still considered occasional and marginal (Earhart and Johnson 1970, Korpimäki 1988), which our results confirm. But the study by Hayward et al. (1993) indicates that insects may sometimes be relatively abundant (Table 4). Nonetheless, they represent only a negligible portion of the biomass taken by boreal owls.

In 2003 and 2004, the Gapper's red-backed vole was unquestionably the dominant species among the specimens caught along the Natashquan River (Maisonneuve 2004 and 2005), accounting for more than 85% of captures. The dramatic decline in the number of captures noted in 2005 is attributable in large part to the almost complete disappearance of this species. This notable decline in the number of Gapper's red-backed voles contradicts the theory that communities of small mammals dominated by species of the genus *Clethrionomys* would be less affected by high-amplitude cyclical fluctuations than communities dominated by species of the genus *Microtus* (Hanski et al. 2001). That theory was based on results obtained in Alaska where voles of the genus *Clethrionomys* were relatively stable, but voles of the genus *Microtus* were cyclical (Whitney and Feist 1984). Other results from Siberia supported that prediction as well. A four-year cycle was observed in a very diversified community of small mammals on flood plains

containing very productive habitats (Sheftel 1989), whereas, on other sites in the same region with habitats that were probably poorer, the communities of small mammals dominated by the genus *Clethrionomys* did not present cyclical fluctuations (Henttonen et al. 1985). Obviously, long-term monitoring of the small mammal populations in the North Shore region would bring further clarification to the study of the cycles of these populations in North America.

Even though our results indicate that the Gapper's red-backed vole is not particularly targeted by boreal owls (Table 3 and Figure 3), its very considerable abundance in the environment nevertheless makes it the main prey. A parallel can be drawn here with the situation in Scandinavia where the very considerable abundance of *Clethrionomys glareolus* makes that species the main prey of the boreal owl, even though the boreal owl particularly targets other species (Korpimäki 1981). The particular importance of the Gapper's red-backed vole has been noted as well in the western part of North America, where years of low abundance of this species correspond with years of poor boreal owl breeding (Hayward et al. 1993). Our results, although they are very partial and do not cover a long period, also tend to point to the considerable importance of the Gapper's red-backed vole for boreal owls in eastern North America.

The heather vole was absent from the captures made in 2005 along the Natashquan River, whereas it ranked second in 2003 and 2004, accounting for 8% of captures (Maisonneuve 2004 and 2005). Generally, the abundance of this species is so low that most studies involving the trapping of small mammals merely mention its presence. The relatively high capture success that we obtained with the heather vole (up to 10 captures/100 trap-nights) contrasts strongly with the small number of abundance indicators mentioned in the literature (Table 5). Only one other study, carried out in the jack pine (*Pinus banksiana*) forests of Ontario, indicates similar values (Naylor et al. 1985). Although the heather vole is much less abundant than the Gapper's red-backed vole, it seems to be particularly important for boreal owls, at least during nesting season. It accounted for more than one-third of the remains of identified prey in the nesting boxes, even in the control sector, where this species was not detected during the 2004 trapping campaign.

The heather vole was therefore taken in a proportion that greatly exceeded its availability in the environment that same year (Table 3). One might believe that the heather vole population underwent a marked decline between the spring, when prey accumulated in the nesting boxes, and September, when the trapping was carried out. But that hypothesis is called into question by the fact that the relative abundance of the heather vole in the captures made the previous fall (2003) was similar to what it was in the fall of 2004 (Figure 3). It therefore seems that boreal owls seek out heather voles when they are hunting or else that the behaviour of that species of small mammal makes it particularly vulnerable to predation by raptors during breeding season. The heather vole prefers relatively open habitats containing heath (Krebs and Wingate 1976, Naylor et al. 1985) that sometimes results from old fires (Simon et al. 1998). It is possible that this species' frequentation of open areas makes it easier for boreal owls to catch them, in comparison with the red-backed vole, which, although very abundant, generally lives in more closed environments where the dense vegetation makes them less vulnerable. That fluctuation in vulnerability has also been demonstrated in Scandinavia, where the main prey of the boreal owl, *Clethrionomys glareolus*, a forest species, is often selected in a smaller proportion than species of the genus *Microtus*, which inhabit more open environments along forest edges (Korpimäki 1981). The relative proportion of the different species in the diet of boreal owls is likely to vary on a seasonal basis, owing mainly to variations in the snow cover that shelters small mammals from predation and that can vary from one habitat to the next (Sonerud 1986). It is therefore possible that, within the areas frequented by boreal owls, the heather vole inhabits microhabitats where the snow melts more quickly, thereby making it more vulnerable to predation at certain times.

Impact of Forest Fires on the Project

There were a particularly large number of forest fires in Quebec in 2005. The one that was observed along the Natashquan River, within the boundaries of the training zone, was the fire that burned in the most easterly region of Quebec that year (Figure 4). The overlaying of the GPS locations of our nesting boxes on the digitized boundaries of that forest fire enable us to estimate that nearly 50 nesting boxes were affected.

In the event that continuing this project is considered relevant, it would be a good idea to maintain an equivalent number of nesting boxes in the training area and the control sector. We would therefore have to consider the possibility of replacing the burned nesting boxes with an equivalent number of nesting boxes in a sector untouched by the fire. Ideally, those new nesting boxes should be installed in habitats similar to those found along the Natashquan and Aguanish rivers, as well as along a navigable watercourse to facilitate access and visits. Among the watercourses located near our study areas, the Natashquan Ouest River (also called the Cormier River by the residents of Natashquan) is one of the few that is easily navigable, and the habitats found on its banks are very similar to those in the area where the network of nesting boxes is already installed. Only the downstream section, near the junction with the main stem of the Natashquan River, has stands of hardwoods resulting from old fires that would not be suitable. The replacement nesting boxes could therefore easily be installed upstream, above the limit of those hardwood stands.

CONCLUSION AND RECOMMENDATIONS

It is obvious that our study of the diet of boreal owls in the Natashquan region is based on a relatively small number of nesting boxes (and therefore, of individuals) and that the data were collected during a single season. Analysis of the nesting box contents collected in 2003 and 2004 in the Sept-Îles region may eventually enable us to clarify that knowledge. Despite those limitations, the results obtained demonstrate the boreal owl's considerable dependence on two main species that seem to undergo marked cyclical fluctuations in their populations. It is also obvious that those populations crashed in 2005 and that that phenomenon prevented boreal owls from nesting.

In Scandinavia, large proportions of boreal owls generally resume nesting the year after such a crash. It would be presumptuous to say that the same conditions favouring such a fast resumption of nesting exist in Quebec as well, but it would be quite easy to check this out at little cost. Since the same conditions seem to exist in the Sept-Îles and Natashquan regions, a visit to the nesting boxes in the Sept-Îles network in April 2006 would give a quick idea of whether boreal owl nesting had resumed or not. Since that network is located along a highway, it would be relatively easy and inexpensive to pay it a visit. In the event that the low-level flights are maintained in sufficient numbers and that continuing the work to evaluate their impact on wildlife in the river valleys is deemed necessary, the results obtained for the network of nesting boxes in Sept-Îles would help to guide the work. Consequently, if it turned out that the occupancy rate of the Sept-Îles nesting boxes was considered sufficient, the monitoring of the network of nesting boxes on the Natashquan and Aguanish rivers could resume in May 2006, a time when it becomes possible to get to the area by boat. In the opposite case, the same process could be repeated in 2007.

Last of all, if the hope is to continue the work, we should consider the possibility of replacing the nesting boxes that were burned in 2005 with an equivalent number of nesting boxes along an accessible section of river in the same region. And even if the low-level flying does not continue, it bears mentioning that the device and the methods

developed in connection with this project remain entirely exportable. They could be used in any other project aimed at evaluating the effects of various human activities on the boreal owl. Consequently, before any thought is given to reproducing such a device elsewhere, it might be worthwhile to check out the effectiveness of the anti-predator devices installed on our nesting boxes so that any corrective measures required can be taken in order to maximize the chances of success.

ACKNOWLEDGEMENTS

I would like to thank Bruno Baillargeon and Raymond McNicoll of the *Direction de la recherche sur la faune* (MRNF), Richard Audy and Alain Chenel of the *Direction de l'aménagement de la faune de la Côte-Nord* (MRNF), and Jean Wapistan of the Innu community of Natashquan for their participation in the field work. Philippe Beaupré, Raymond McNicoll, and Sylvain St-Onge of the *Direction de la recherche sur la faune* (MRNF) carried out the work to identify the small mammals captured, as well as the work to clean and identify the remains of prey found in the nesting boxes. Lastly, Nathalie Tessier, of ConservAction ACGT Inc., conducted the genetic identification of the specimens of the genus *Peromyscus*.

The Institute for Environmental Monitoring and Research and the *Ministère des Ressources naturelles et de la Faune*, sector *Faune Québec*, provided the funding for this project.

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Table 1. Abundance and species of small mammals captured within and outside the military training area (MTA) in closed spruce stands located along the Natashquan River, July 2005

	MTA	Control	Total
Gapper's red-backed vole <i>Clethrionomys gapperi</i>	3	12	15
Deer mouse <i>Peromyscus maniculatus</i>	0	2	2
Star-nosed mole <i>Condylura cristata</i>	1	0	1
Masked shrew <i>Sorex cinereus</i>	4	10	14
TOTAL	8	24	32

Table 2. Identification of the remains of prey recovered from 12 nesting boxes occupied by boreal owls along the Natashquan and Aguanish rivers, 2004

			<i>n</i>	%
Mammals				
	Microtidae			
	Arvicolinae	<i>Clethrionomys gapperi</i>	98	35.5
		<i>Phenacomys intermedius</i>	55	19.9
		<i>Synaptomys borealis</i>	11	4.0
		<i>Microtus pennsylvanicus</i>	3	1.1
		Unidentified	104	36.7
		Subtotal	271	98.2
	Neotominae	<i>Peromyscus maniculatus</i>	1	0.4
		Subtotal	1	0.4
	Soricidae	<i>Sorex</i> spp.	2	0.7
		Subtotal	2	0.7
	Total		274	99.3
Amphibians	Ranidae	<i>Rana</i> sp.	1	0.4
Insects	Odonata	Aeshnoidae	1	0.4
Grand total			276	100.0

Table 3. Availability and observed and anticipated use of different species of small mammals by boreal owls, 2004

Species	Relative abundance during trapping (availability)	Number of specimens in nesting boxes (use)		95% confidence interval
		Observed	Anticipated	
<i>Clethrionomys gapperi</i>	85.2%	98	137	0.20 - 0.35
<i>Phenacomys intermedius</i>	7.5%	55	20	-0.32 - -0.18^a
<i>Synaptomys borealis</i>	2.5%	11	5	-0.08 - 0.00
Other rodents	2.1%	4	4	-0.03 - 0.02
<i>Sorex</i> spp.	2.7%	2	4	-0.01 - 0.03

^aA confidence interval with two negative extremes indicates that the species is selected (Marcum and Loftgaarden 1980)

Table 4. Composition (%) of the diet of boreal owls during the breeding season in different regions of North America

	Quebec ^a (n=276)	Colorado ^b (n=72)	Montana, Idaho, Wyoming ^c (n=672)	Alaska ^d (n=778)
Mammals				
<i>Clethrionomys gapperi</i>	36	54	31	
<i>Clethrionomys rutilus</i>				48
<i>Phenacomys intermedius</i>	20		4	
<i>Synaptomys borealis</i>	4			
<i>Microtus pennsylvanicus</i>	1			42
<i>Microtus longicaudus</i>		13		
<i>Microtus montanus</i>		13		
<i>Microtus richardsoni</i>			tr	
<i>Microtus xanthognathus</i>				4
<i>Lemmus sibiricus</i>				tr
Unidentified voles	37	6	9	
<i>Peromyscus maniculatus</i>	tr	1	6	
<i>Sorex</i> spp.	tr	6	11	3
<i>Thomomys talpoides</i>			10	
<i>Glaucomyssabrinus</i>			tr	
<i>Tamias amoenus</i>			2	
<i>Zapus princeps</i>			2	
<i>Zapus hudsonius</i>				tr
<i>Ochonota princeps</i>			tr	
<i>Neotoma cinerea</i>			tr	
<i>Lepus americanus</i>				tr
<i>Mustela</i> spp.			tr	
Total mammals	98	93	77	97
Birds		7	5	3
Amphibians	tr			
Insects	tr		18	

^aOur study

^bRyder et al., 1987

^cHayward et al., 1993

^dWhitman, 2001

Table 5. Capture success (number/100 trap-nights) of heather voles recorded in different studies carried out in Canada

Capture success (/100 trap-nights)		Region	Study
Maximum	Mean		
2.96	--	Manitoba	Foster, 1961
0.22	0.06	Yukon	Krebs and Wingate, 1976
3.6	0.9	Ontario	Martell, 1983
1.17	0.46	Alberta	Millar et al., 1985
9.59	1.83	Ontario	Naylor et al., 1985
1.25	0.18	Labrador	Simon et al., 1998
9.97	2.09	Quebec	Our study

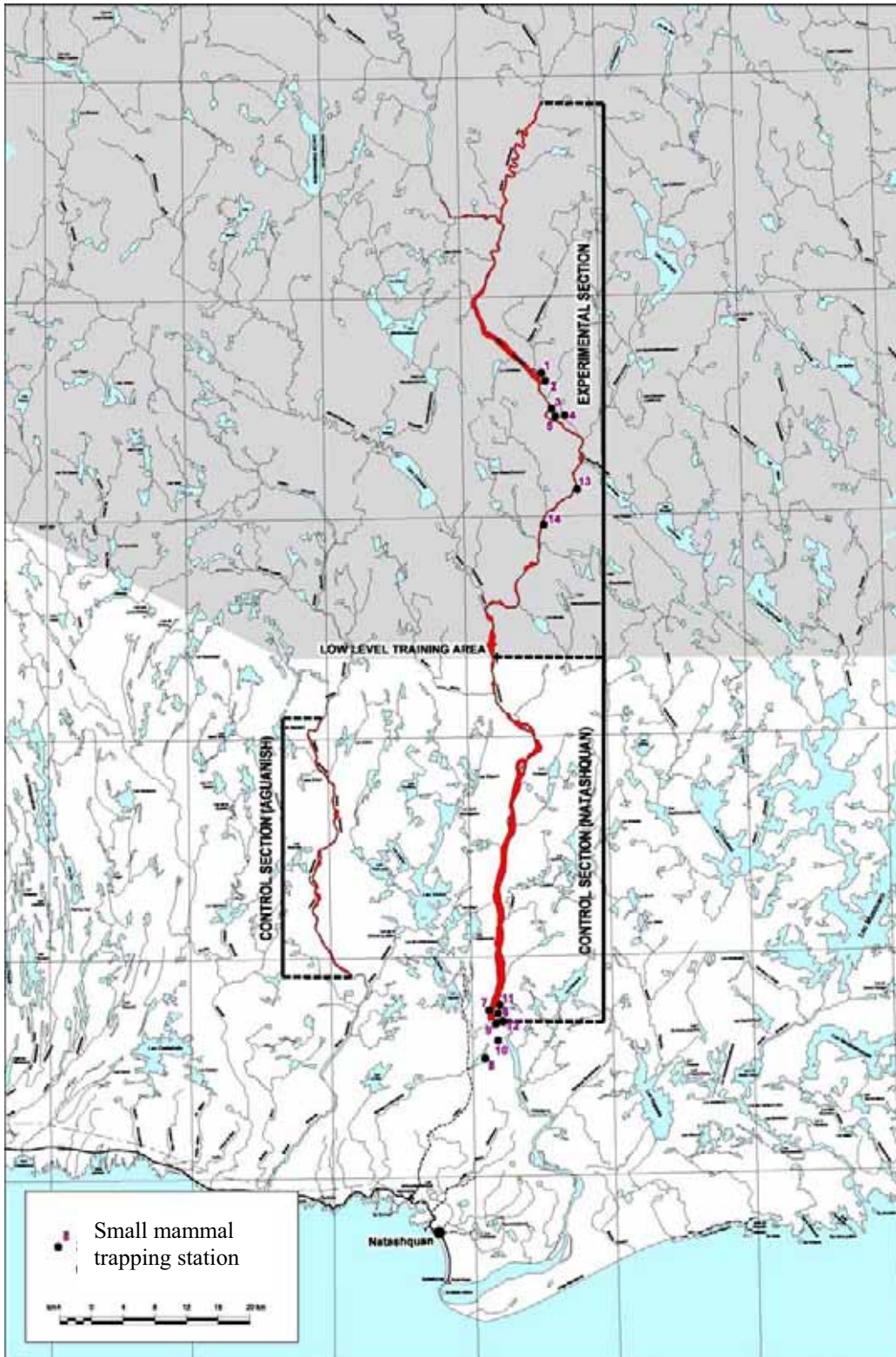


Figure 1. Location of the river sections under study and the small mammal trapping stations

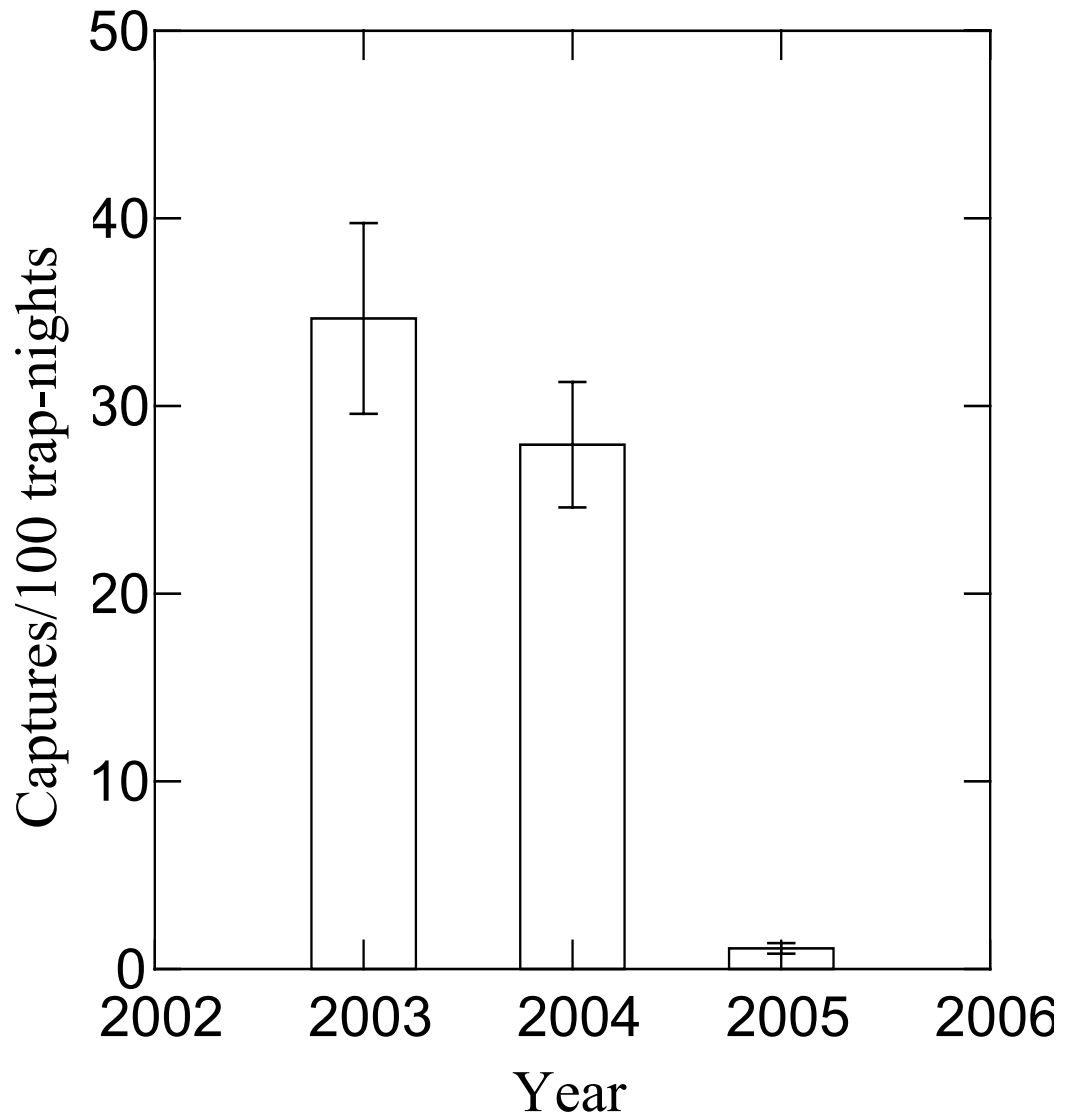


Figure 2. Small mammal capture success on all 10 trapping sites located in closed spruce stands along the Natashquan River

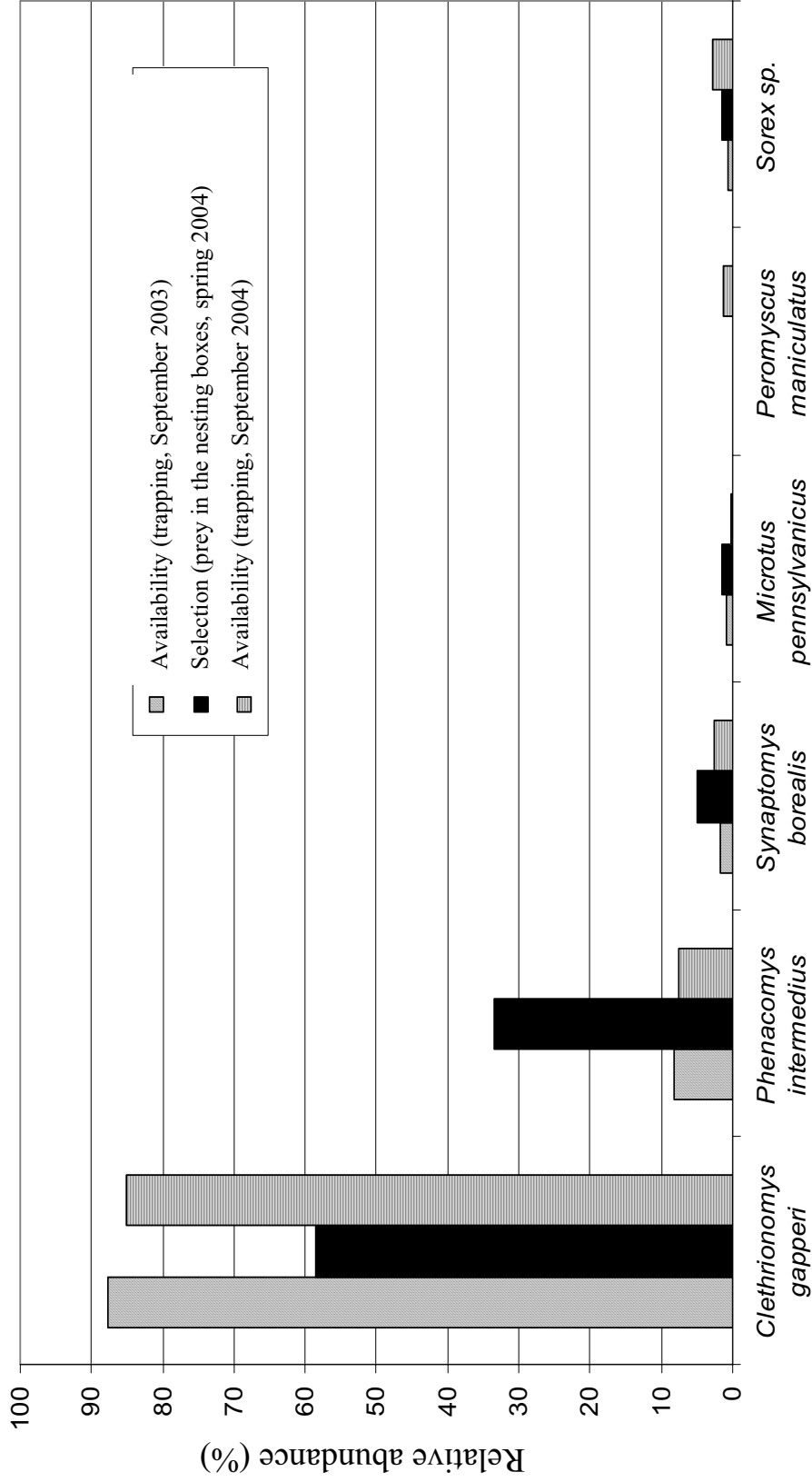


Figure 3. Relative abundance of different species of small mammals identified among the remains of prey found in the nesting boxes occupied by boreal owls in spring 2004 and among the specimens harvested during the trapping campaigns carried out in September 2003 and 2004

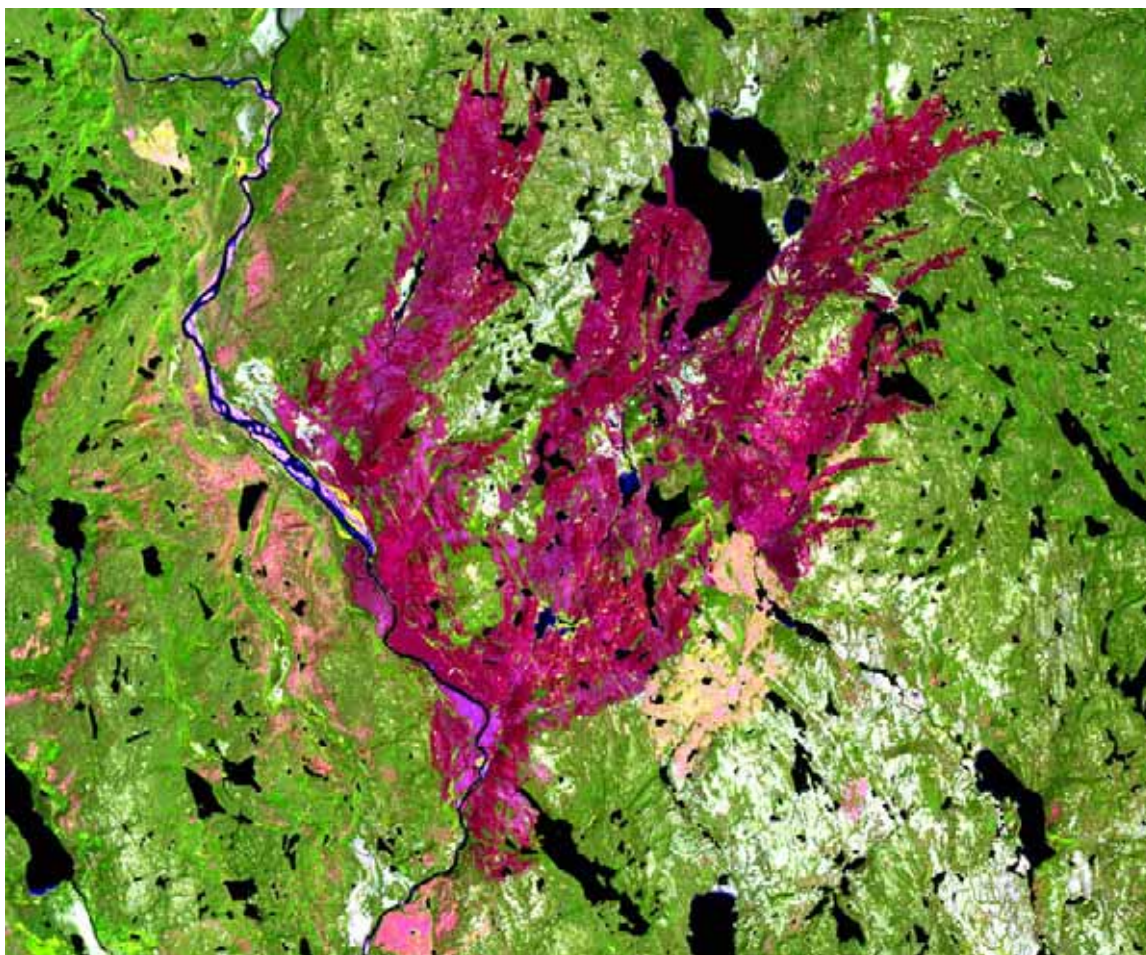


Figure 4. Boundaries of the forest fire that affected the Natashquan River sector in summer 2005 (Source: Direction des inventaires forestiers, Ministère des Ressources naturelles et de la Faune)